Averaging kernels and their use in validating AIRS temperature and water vapor

A work in progress

Bill Irion - April 17, 2008

With thanks to Evan Manning and Van Dang

What's an averaging kernel?

The averaging kernel matrix is a measure of how and where the retrieval is sensitive to changes in the "true" state.

Retrieved state vector

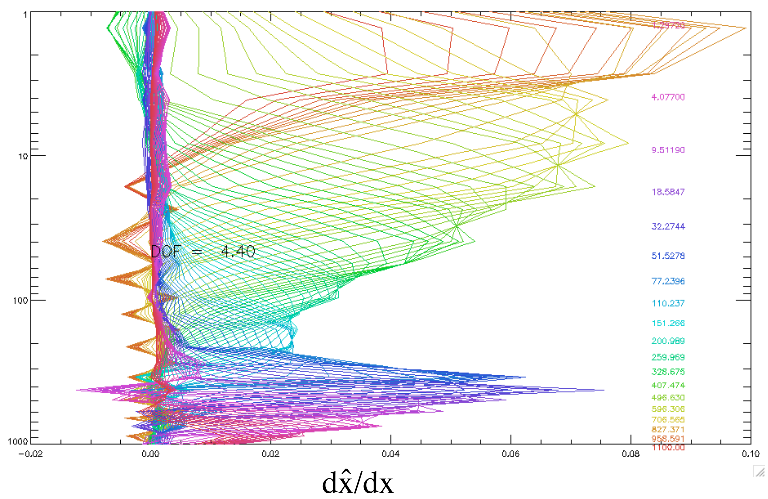
$$A = \frac{\partial \hat{x}}{\partial x}$$

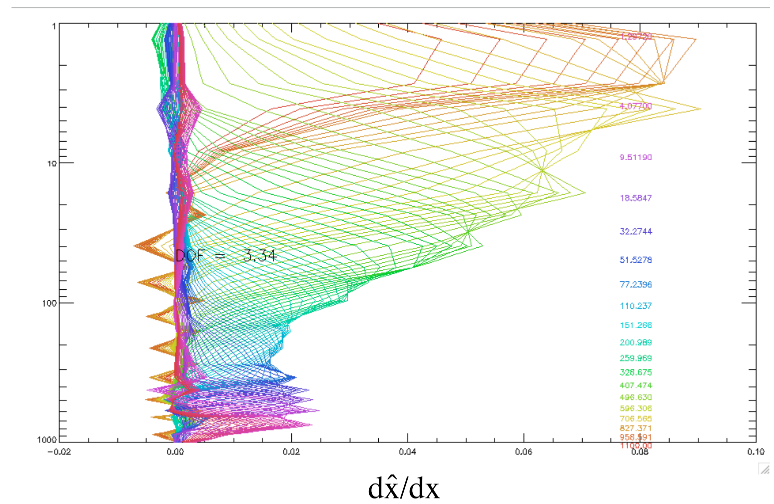
"True" state vector

For AIRS averaging kernel derivation and discussion, see *Maddy and Barnet,* Vertical resolution estimates in Version 5 of AIRS operational retrievals, submitted to *IEEE Trans. Geosci. Remote Sensing*, 2007

Sample temperature averaging kernels

2005.07.12 Alajuela, Costa Rica





- AK is affected by signal-to-noise and local conditions (e.g. temperature gradient)

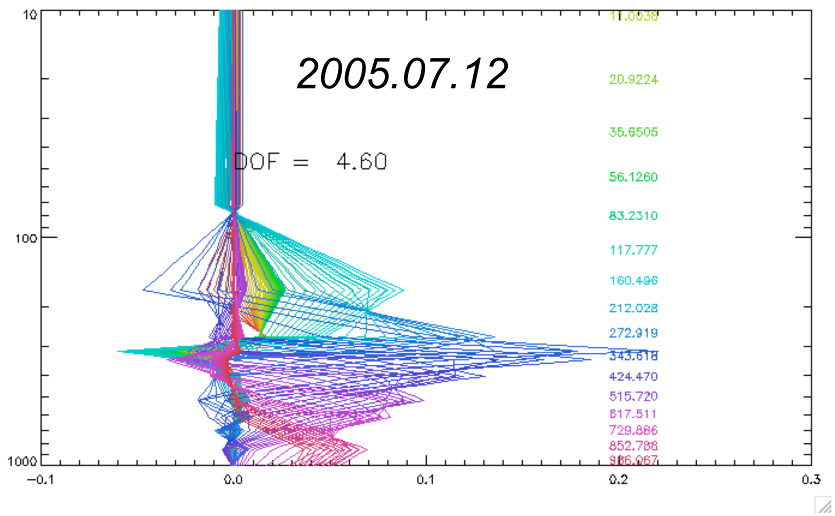
- The depth (x-axis) of a curve is indicative of sensitivity

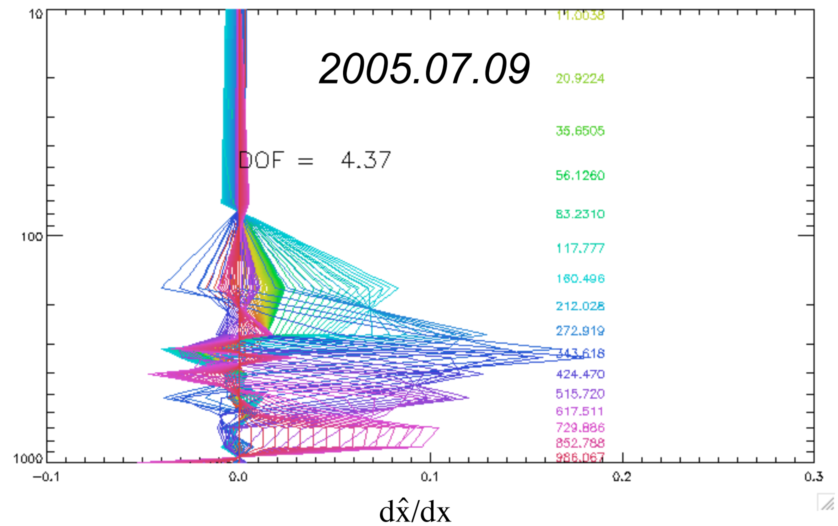
- The width (y-axis) is indicative of vertical resolution

- The trace of the AK is the number of degrees of freedom

Sample water vapor averaging kernels

Alajuela, Costa Rica





$d\hat{x}/dx$

$d\hat{x}/dx$

- Again, AK is affected by signal-to-noise and local conditions
- Sensitivity decreases in upper troposphere and is absent in stratosphere

Using Averaging Kernels with correlative “truth” data

- Every retrieval uses a combination of observed data and an *a priori*

$$\mathbf{x}_{est} = \mathbf{x}_0 + \mathbf{A}'(\mathbf{x}_T - \mathbf{x}_0)$$

- If sensitivity were perfect, $\mathbf{A}' = \mathbf{I}$
- If $\mathbf{x}_T$ were replaced by “truth” (say, a radiosonde profile), then $\mathbf{x}_{est}$ would be a measure of what the instrument should have returned given its sensitivity.
- Regression adds information that is not quantified

Procedure

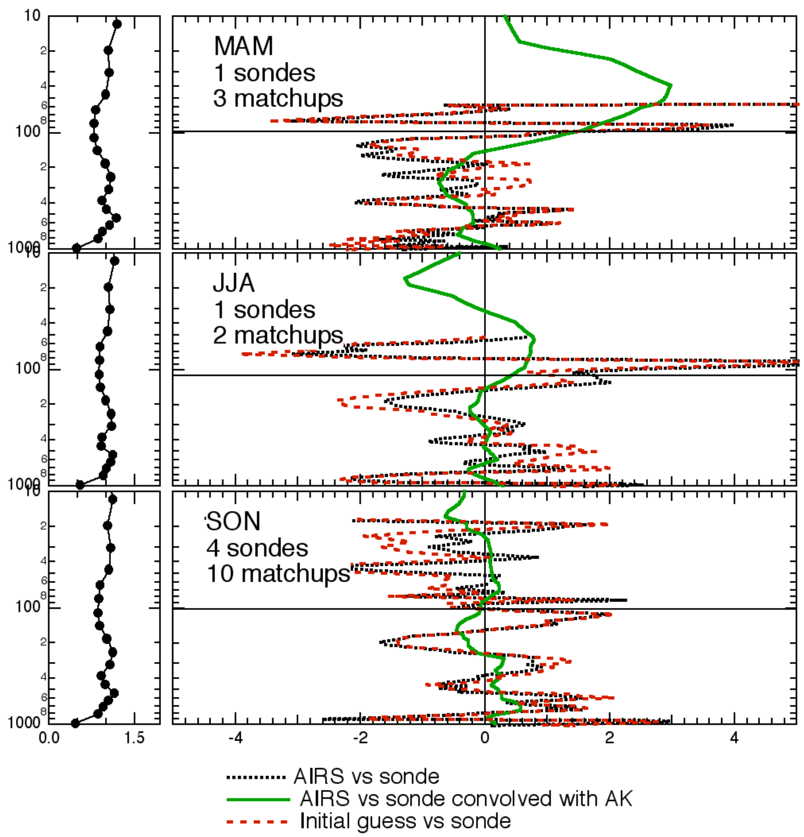
- Radiosonde data from Tobin, Voemel, McMillan, ARM SGP and NSA etc. (more work in progress)
- Additional temperature data from WOUDC (great stuff!)
- Slab columns calculated for water on AIRS 100-level grid
- AIRS retrievals used to fill in “truth” above range of sondes
- Sonde data must at least reach tropopause
- Temperature quality flags = 0 for temperature comparisons, water quality flag = 0 for water
- 1 hr, 50 km matchup range for temperature and water
- “Kerning” calculation on sonde data uses ln(slab column) for water:

$$\ln \mathbf{x}_{est} = \ln \mathbf{x}_0 + \mathbf{A}'(\ln \mathbf{x}_T - \ln \mathbf{x}_0)$$

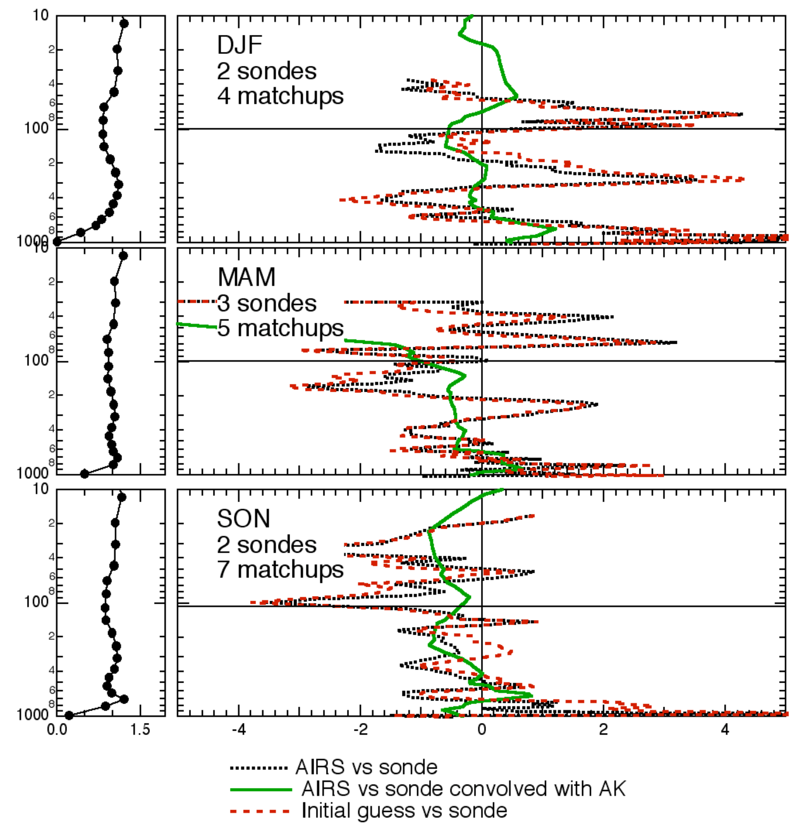
Some average temperature comparisons

Verticality
(sum of row
Of Avg. Kernel)

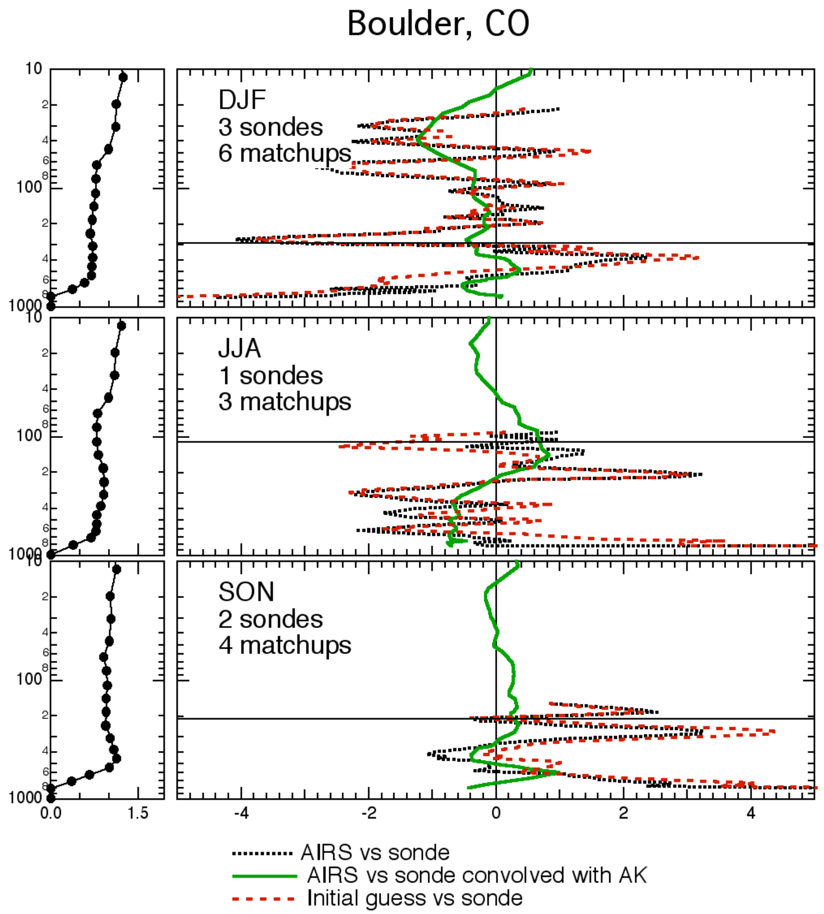
San Cristobal

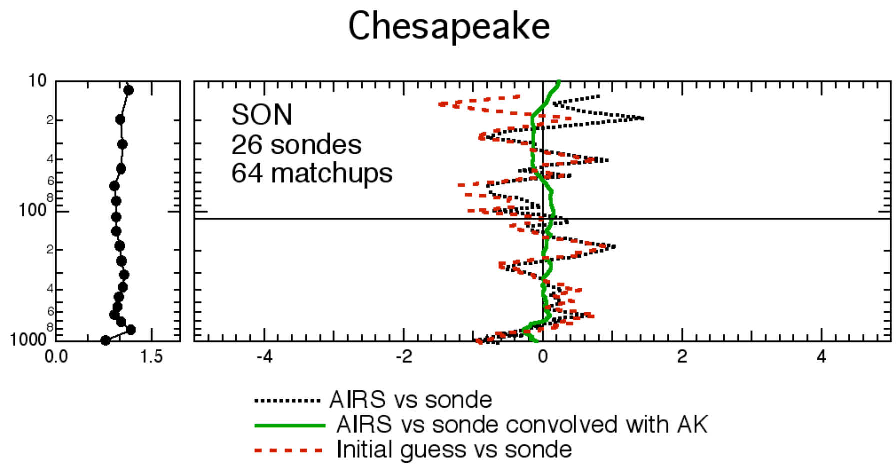


Hilo, Hawaii

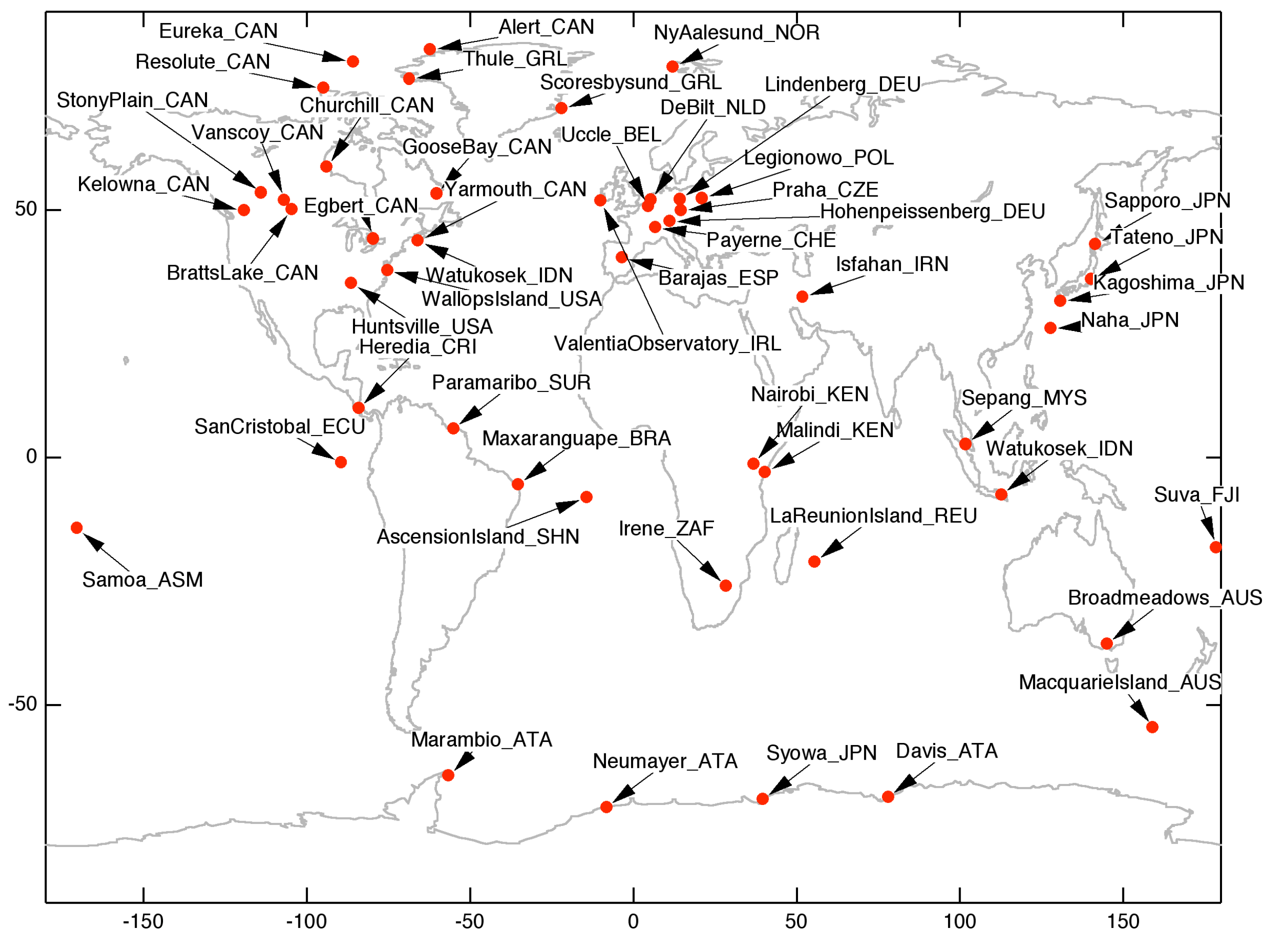


More average temperature comparisons

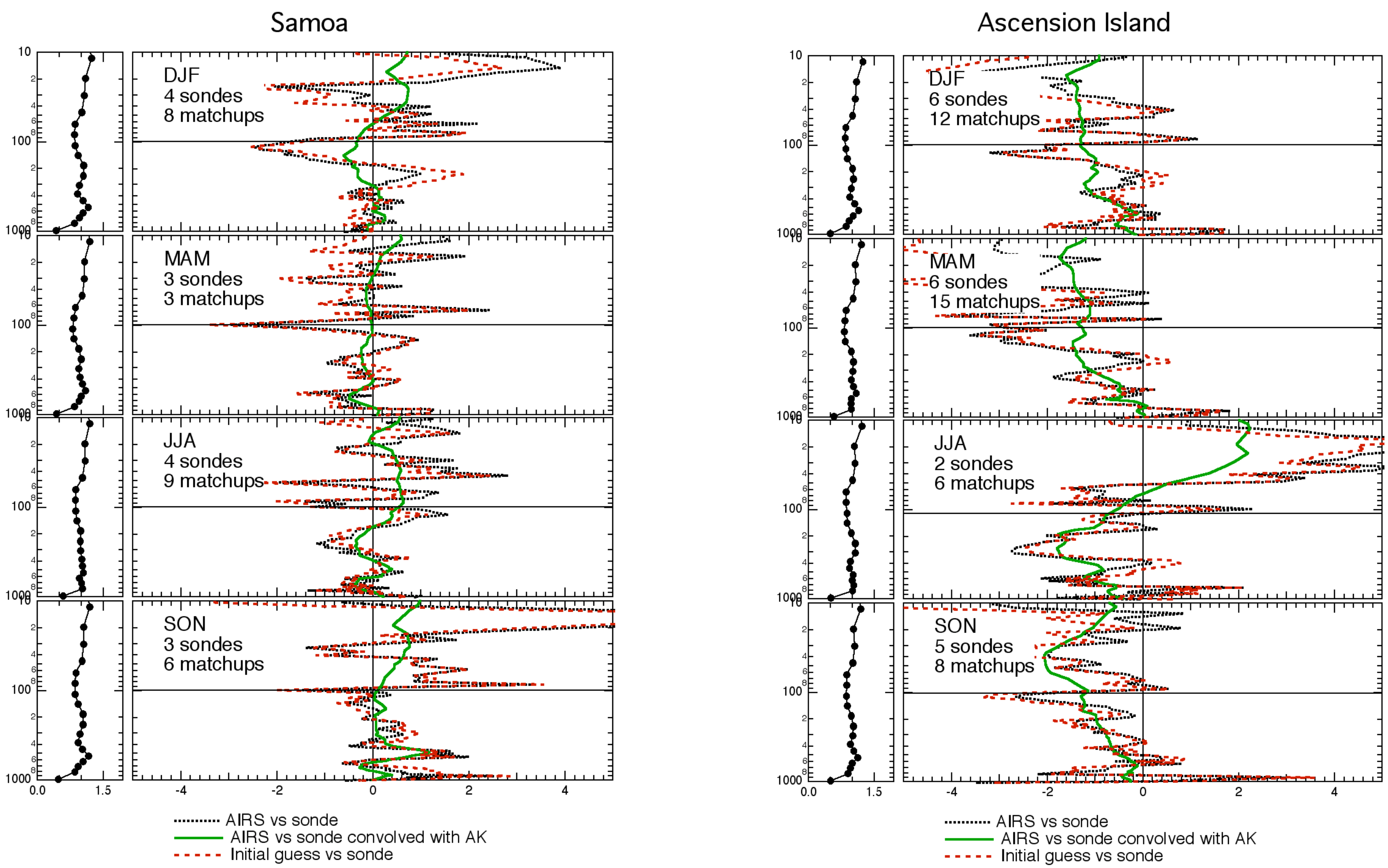




WOUDC locations

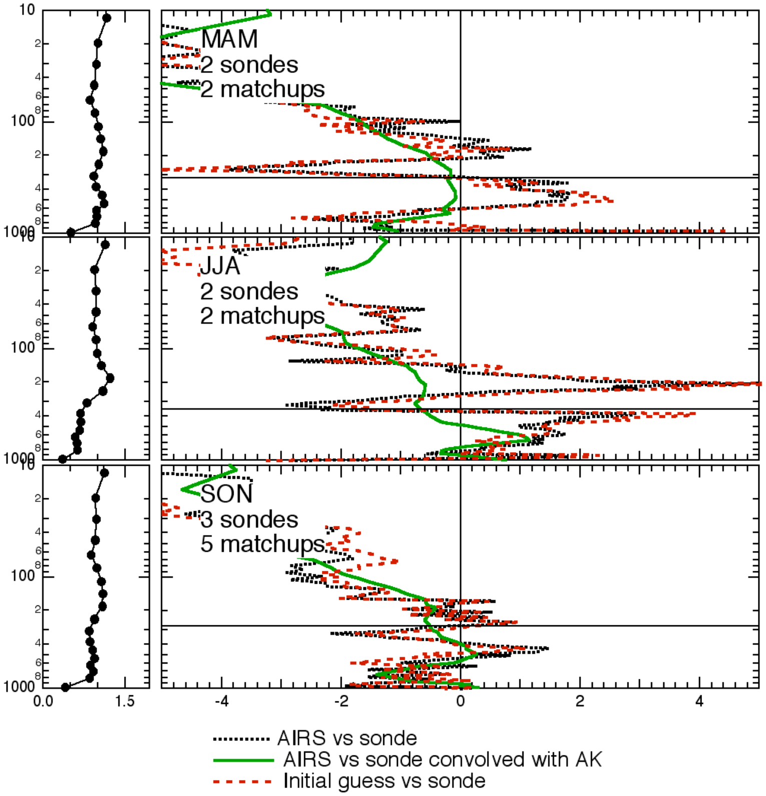


Tropical results (WOUDC sondes)

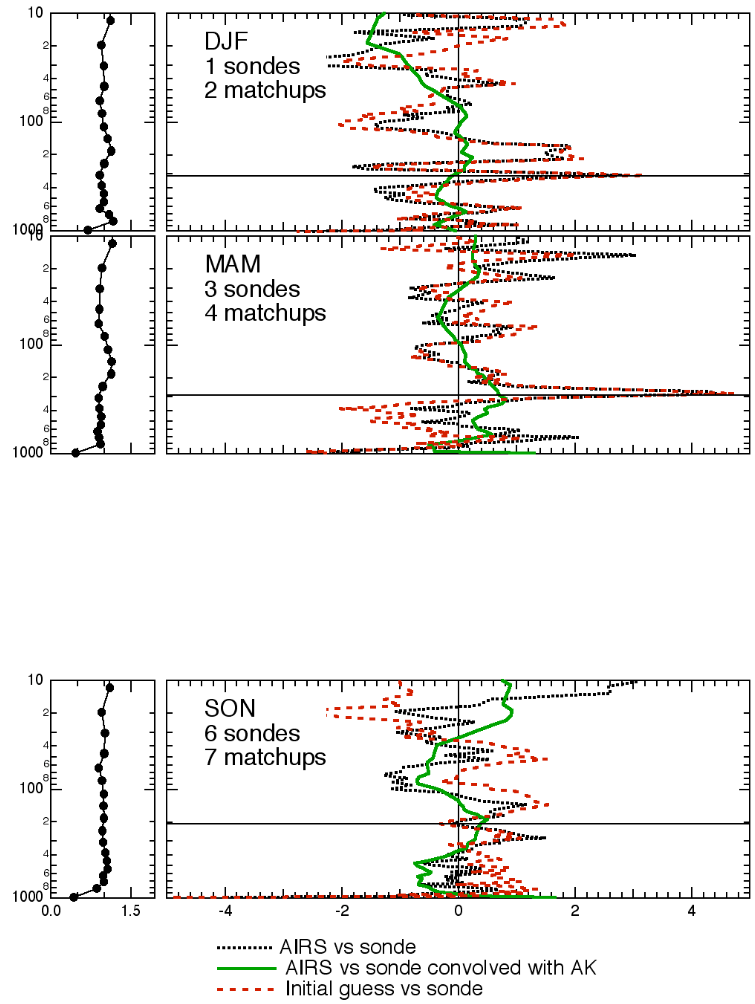


Polar Results (WOUDC sondes)

Thule, Greenland

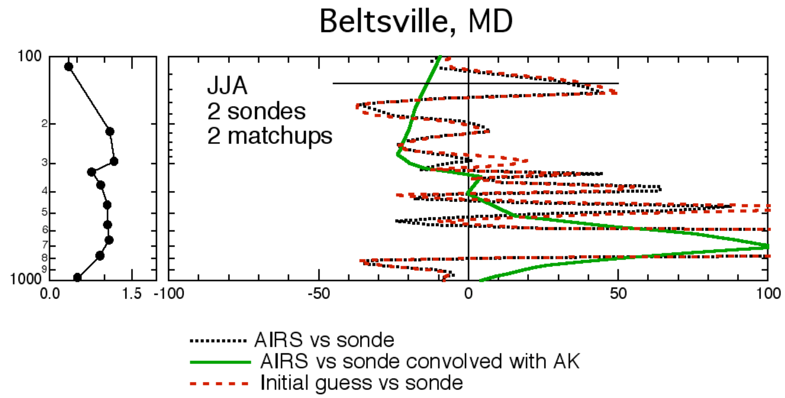


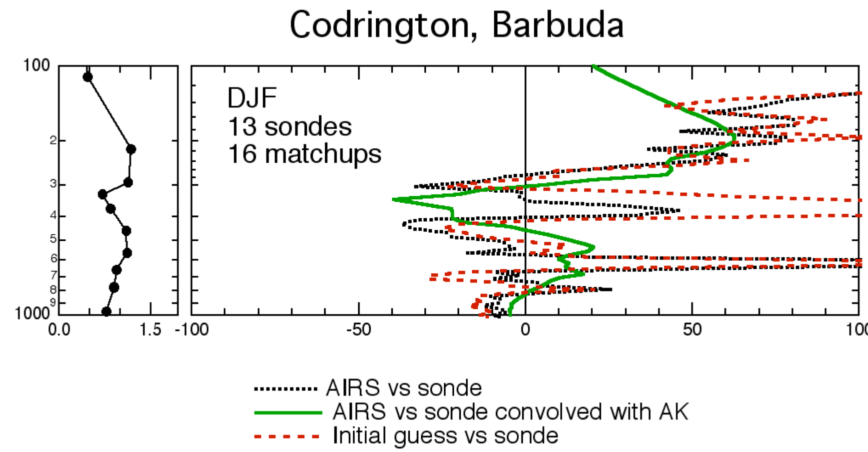
Syowa, Antarctica

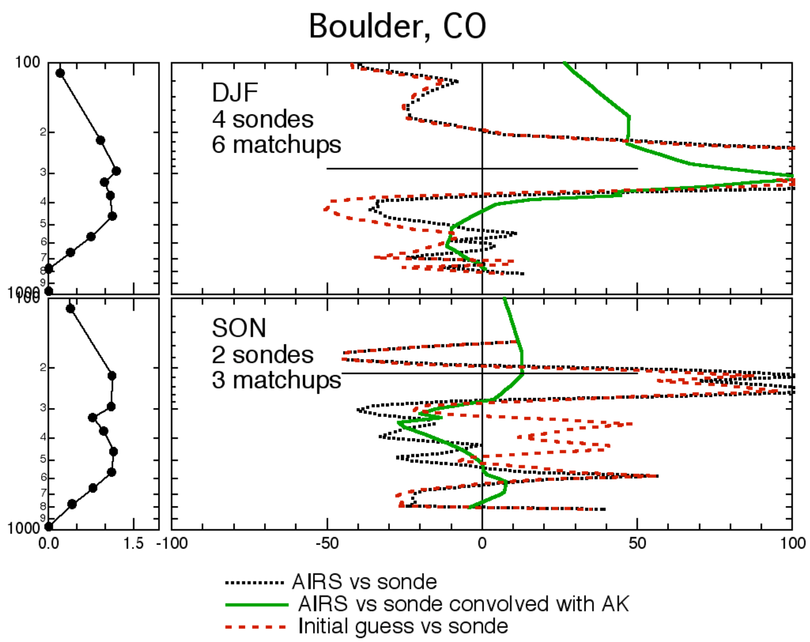


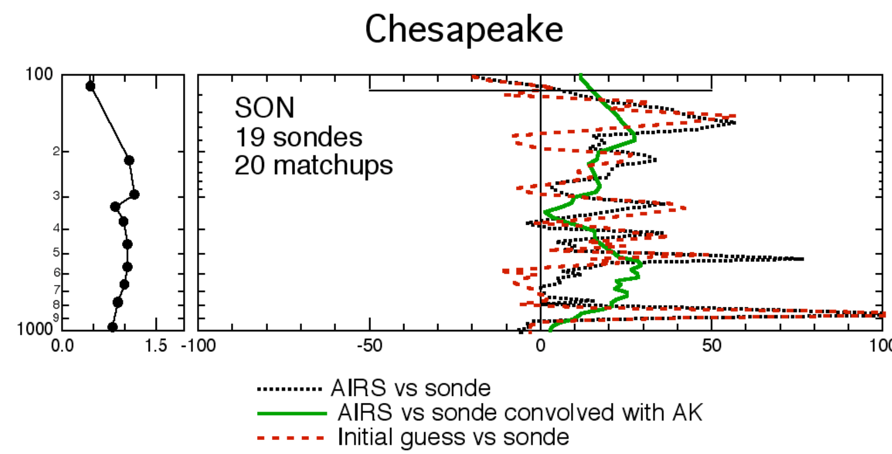
Water vapor comparisons

(AIRS – sonde) / sonde (%)









Conclusions

- Results often indicate improvement over *a priori* for temperature and water, but retrieval can often not recover from poor first guess.
- More work needed on collating and quality–checking radiosondes
- Work on mapping vertical resolutions